APPENDIX E

EXPRESS MAIL LABEL NO.: EL386270487US

Abstract

This appendix briefly explains the function of the registration and the Line-Width measurements in the SIP. Line-Width is typically based on the CELs and the morphological skeleton, while the registration is typically based on the skeleton features only.

The registration

Most methods in the SIP compare a 'learned' panel to an actually scanned one (the 'inspect' phase). The function of the registration in the SIP, is to find linear transformation between points of the scanned panel to the reference coordinate system. The registration typically uses the output of the hardware morphological features extractor. It finds these transformations by using both features of the 'learn' and the 'inspect' different phases. Human intervention is not typically needed for this process, both for learning and inspecting.

The features are taken from the beginning of the panel, and are of limited number due to limitations in processing time determined by the computer speed, and the requirements from the SIP system. The numbers are typically around several hundreds.

It is also deals with limited movement, e.g. rotation. The shift form rigid transformation is preferably small (in the order of magnification up to 1% in x and y, and sheering angle preferably smaller than about 0.01 radian).

The registration is divided for two phases in the inspect. The first one is to find the initial transformation, and the next one, is to keep the panel in the best transformation during the scan. The second part is called the 'dynamic registration'.

The initial registration transformation method

learn process:

This process works on features of the learned panel, for illustration called group R.

Collect the first predetermined number of features from the beginning of the learned panel.

Sort the features of R according to x and y.

inspect process:

This process computes the registration transformation. It uses the features of R, and features which are collected at the inspection of the panel. These features are called herein for illustration, group I.

Collect the features in exact manner as in the learn phase.

Sort the features of I according to x and y.

Create a table with number of entries identical to the number of features in R, with entry N of the table representing feature N in R.

For each of the ordered features in I:

1. Push-back a copy of that features to all table entries which represent the features in R, which are in distance less the maximum miss registration (The table contains copies of features in I only).

For-each two pairs of features match between I to R combinations:

1. If the transformation is not rigid, move to next combination

2. If pairs are in S (set of pairs which will be defined below), move to next combination.

3. Find the transformation from I to R for this pair. if transformation is not in mis-registration maximum allowed angle or movement, move to the next combination.

4. Find all features down in the table that conform with the table entry representative feature in R using the transformation (if distance is small up to noise between transformed I feature and its R).

5. The features address which conform with the transformation are in a group - all pairs of combination of them are put to the set S

Move to next two pairs combination.

The registration transformation is the transformation which was computed with the maximum number of matches.

The Dynamic registration.

Dynamic registration is a method for tracing the most correct transformation during panel scan. Initial transformation is already known. A 'Matcher' process sends pairs of matched features to it. The core of its activity is computation of the best transformation which exists between two sets of matched points. The best

transformation is achieved using the least square method. Find the linear transformation which minimize the square distance of the pairs. Mathematically this can be described as shown in Equation 1.

Solving this minimization problem yields a simple solution, which is easy to handle. For each new matched pair some registers are update. Calculation of the best transformation is by using them.

Line-Width measurements

Line-Width process measures the width of the conductors, and the space between them. It finds violations in their measures by comparing the sizes of the 'learn' to the 'inspect' panel. The amount of the deviation is given by the user, using a graphical human interface that allows one to tell for each region in the panel, what are the used limitations. Line-Width is using the CELs and is done by software. It is officious due to its simplicity.

The measurements:

The measurement are taken in 4 directions: East, West, South-East, and South-West, i.e., they are typically taken each 360/8 = 45 degrees. The measure is taken perpendicularly to the morphological skeleton. A stream of CELs and Skeletons are the input for this method. The Skeleton typically holds the information of what is the perpendicular direction of width measurement. Each CEL or Skeleton feature belong to a certain state machine, in each of the directions. A state machine allows measurement if CEL, Skeleton, CEL combination found, otherwise no measure is output. The measurements uses the sub pixel CEL accuracy and tables exist for output information of the diagonals intersection with the cells.

Learn process:

The 'learn' coordinate system is divided to a small square boxes. The task of this phase is eventually to tell for each of this box, what is the minimum and maximum allowed measure. The knowledge is gathered by measuring the learned panel and putting the measures to the boxes. A statistical analysis is done to determine if a box is legitimate, and in a legitimate case to determine whether it is good or bad. In other cases usually minimal measure is put for a reference box. A reference box contains statistics also of measures near it in order to resolve the 1 to 2 pixels accuracy of features after

transformation.

Inspect process:

The inspect process is more simple - each measure is checked against the appropriate learn box, for being in the [min, max] range. The learn box is found by transforming the inspection coordinate to learn coordinate system, using the registration transformation.

EQUATION 1

$$\min\left(\sum_{i=0}^{N} \| \vec{p}_i - Tx\,\vec{Q}_i \|^2 \right)$$

where p_I matches Q_I belong to the sets P Q respectively.